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**SORGHUM IS A PROMISING FEED RESOURCE FOR ANIMAL  
HUSBANDRY IN THE CONTEXT OF CLIMATE CHANGE  
(Review article)**

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*The article is devoted to an overview of trends, volumes and state of sorghum cultivation in Ukraine and on a global scale. Sorghum is one of the most important forage, industrial and food crops, which is characterized by high drought resistance, ecological plasticity and versatility of use. It ranks fifth among the most widespread grain crops in the world, grown in more than 85 countries on an area of about 50 million hectares. The main producers are the United States, Australia, Argentina, China, Mexico and Japan.*

*Ukraine is one of the key European producers of sorghum, actively introducing modern agricultural technologies and increasing its export potential. Despite the temporary reduction in acreage, they are projected to expand significantly in the coming years.*

*Historical aspects of sorghum domestication and the variety of its use are traced. Sorghum has a long history, it was grown in Ancient Egypt more than 3000 years ago. It has spread all over the world, adapting to different climatic conditions. Thanks to breeding achievements, various types of sorghum were bred: grain, sugar, broom and fodder, each of which has its own specific application.*

*The article considers the features and advantages of this promising crop for our climatic conditions. Attention is focused not only on the botanical features of sorghum as a fodder crop in the agro-industrial complex of Ukraine, but also on the diversity of its species forms and hybrids.*

*In particular, the main directions of breeding sugar and grain sorghum are analyzed. A comparative analysis of the chemical components of grain sorghum and the content of individual mineral elements in seeds is carried out.*

*The main advantages of sorghum in terms of its resistance to diseases and pests in comparison with the range of forage crops similar in botanical characteristics are evaluated.*

*The article highlights the experience of specialists in using sorghum in feeding farm animals, and its impact on product quality. In animal husbandry, sorghum is used as a highly nutritious feed containing protein, starch and trace elements, which helps to improve the productivity of livestock. Its grain is actively used in the production of mixed feed, gluten-free products and bioethanol, and green mass for the production of silage.*

**Keywords:** sorghum, crop distribution, breeding directions, hybrids, sorghum grain, sorghum silage, animal feeding.



## СОРГО – ПЕРСПЕКТИВНИЙ КОРМОВИЙ РЕСУРС ДЛЯ ТВАРИННИЦТВА В УМОВАХ КЛІМАТИЧНИХ ЗМІН (ОГЛЯДОВА)

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*Стаття присвячена огляду тенденцій, об'ємів і стану вирощування сорго в Україні та у світовому масштабі. Сорго – одна з найважливіших кормових, технічних і продовольчих культур, яка вирізняється високою посухостійкістю, екологічною пластичністю та універсальністю використання. Воно займає п'яте місце серед найбільш поширених зернових культур світу, вирощується у понад 85 країнах на площі близько 50 млн га. Головними виробниками є США, Австралія, Аргентина, Китай, Мексика та Японія.*

*Україна є одним із ключових європейських виробників сорго, активно впроваджуючи сучасні агротехнології та нарощуючи експортний потенціал. Незважаючи на тимчасове скорочення посівних площ, прогнозується їхнє суттєве розширення у найближчі роки.*

*Простежено історичні аспекти одомашнення сорго та різномайття його використання. Сорго має давню історію, його вирощували ще в Давньому Єгипті понад 3000 років тому. Воно поширилось по всьому світу, адаптуючись до різних кліматичних умов. Завдяки селекційним досягненням було виведено різні види сорго: зернове, цукрове, віничне та кормове, кожен із яких має свою специфіку застосування.*

*У статті розглянуто особливості та переваги цієї перспективної для наших кліматичних умов культури. Сконцентровано увагу не лише на ботанічних особливостях сорго як кормової культури в агропромисловому комплексі України, але й на різноманітті його видових форм та гібридів.*

*Зокрема проаналізовано основні напрямки селекції сорго цукрового та зернового. Проведено порівняльний аналіз хімічних складових зернового сорго та вмісту окремих мінеральних елементів в насінні.*

*Оцінено основні плюси сорго щодо його стійкості до хвороб та шкідників порівняно зі спектром подібних за ботанічними характеристиками кормових культур.*

*Висвітлено досвід фахівців в використанні сорго в годівлі сільськогосподарських тварин, та його вплив на якість продукції. У тваринництві сорго використовується як високопоживний корм із вмістом білка, крохмалю та мікроелементів, що сприяє покращенню продуктивності худоби. Його зерно активно застосовують у виробництві комбікормів, безглютенових продуктів і біоетанолу, а зелена маса для виготовлення силосу.*

**Ключові слова:** сорго, поширення культури, напрями селекції, гібриди, сориз, зерно сорго, силос з сорго, годівля тварин.

We live in times of change that occur regardless of our attitude to them. And in such conditions, it is important not only to be able to adapt to new challenges, but also to



try to stay ahead of them. This also applies to the agricultural sector, as one of the most traditional in the global economy.

The use in agricultural production of crops characterized by high yields, resistance to adverse environmental conditions, pests and diseases is one of the sources of increasing the volume of feed production and strengthening the feed base.

Sorghum is the most important fodder, technical and food crop. It is cultivated in many countries of the world on all continents. Different peoples of the world call sorghum culture differently: in Central Asia - jugara, in India - jovar, in China - gaolyan, hundzu, shoshu, in Korea - Su-Su, in Georgia - Gomi, in Asia Minor - Dora, in the African country - Durra, zorrat, in Spain, France - sorgo, etc. This culture got its name for its height from the Latin "sorgos" - "to rise, to rise" (Cardoso, L. M. et al., 2015). In World Agriculture, sorghum ranks fifth among the most common grain crops and is grown in 85 countries around the world on an area of about 50 million hectares. Ga (Rakshit, S. et al., 2014). Such large acreage of sorghum is associated with its unpretentiousness, high environmental plasticity and heat resistance. High productivity, feed advantages and versatility put sorghum among the most promising crops (Hossain, S. et al., 2022; Pravdyva, L. A. et al., 2023; Widodo, S. et al., 2024). Taking into account the relevance of this issue, the aim of the work was to analyze the experience of specialists in using sorghum in feeding farm animals, and its impact on product quality.

Research materials and methods. A systematic review of literature sources is carried out by searching for publications in the databases Scopus, Web of Sciences, Google Scholar, etc., published in Ukrainian and English in recent years in accordance with the inclusion criteria. The systematization of the published data was carried out in order to accumulate modern scientific knowledge on the use of sorghum as a feed crop in cow feeding and its impact on the quality of dairy products to further build their own methodological basis for research in this direction in domestic conditions, taking into account international experience.

Research results. The world's main producers of sorghum are North America and Africa, the main exporters are the United States, Australia and Argentina, and importers are China, Mexico and Japan (Kondratiuk, S. 2018).

It should be noted that Ukraine is assigned one of the key roles in this regard, since our state is already one of the largest producers of this crop in Europe with an area of 70 thousand hectares and a production volume of 256 thousand tons. Another 18 thousand hectares are occupied by fodder sorghum crops. However, in recent seasons, its acreage has significantly decreased, which was due to the higher profitability of corn, soybeans and sunflower. In a few years, the area under sorghum will occupy at least 1-1.3 million hectares, and in 5-10 years it can partially replace corn and even sugar beet. Ukrainian farmers are actively implementing precision farming technologies, which allows them to optimize costs and increase production efficiency.

Sorghum has significant potential for development both domestically and for export. Due to its high nutritional value and versatility of use, sorghum can become a key crop for many farms. Ukrainian farmers have the opportunity to expand their sales markets, including Europe and Asia, where the demand for sorghum is constantly growing (Ozturk, I. 2018).

Sorghum is native to Equatorial Africa. Archaeological finds indicate that the practice of domestication of the culture was transferred from Egypt to Ethiopia around 3000 Years BC.E. on ancient monuments in Egypt, built long before 2200 BC, drawings of harvesting and found sorghum grain, which indicates the cultivation of this culture from time immemorial. Its antiquity is confirmed by ancient monuments in the countries of East and South Asia (Cardoso, L. M. et al., 2015; Smith, C. W. 2000). Sorghum came



to India by land and sea routes. Its cultivation in India is mentioned in Legends dating back to the First Century AD, under the name "cane barley". In this country, grain sorghum is considered the third most important food crop after wheat and rice. It is believed that India and China are secondary foci of origin and formation. It is known that when sorghum genotypes are transferred to new geographical zones, modification variability occurs. In the new conditions, the crop may be more productive and precocious than at home, as a result of which it occupies larger areas. Thus, the sorghum nevrosuum race is not widespread in Africa, and in China and India it is an important national culture (Burgarella, C. et al., 2021). Natural and artificial selection has led to the emergence of new forms that have led to the varieties of sorghum that we now grow (Ge, F. et al., 2022). From India and China, sorghum was imported to Central Asia 2-3 millennia ago.

Weed sorghum was first cultivated and grown in America and Europe earlier than all other cultivated sorghum imported later directly or indirectly from Africa. In China, the first documented mention of sorghum appears as early as the 3rd century AD. The widespread use of sorghum in Italy dates back to the late 17th century. Dried sorghum shoots were collected in the form of brooms and used to clean clothes in Italy, France and Germany. By the 1700s, the widespread use of sorghum in Europe had attracted the attention of Benjamin Franklin. During the 1960s and 1970s, production was moved to Mexico, which is still one of the most significant suppliers of sorghum to the US market. The main sorghum producing countries in southeastern Europe remain Serbia, Hungary and Turkey, with smaller crops in Romania, Bulgaria and Ukraine (Berenji, J. et al., 2011).

In North and South America, the genus *Sorghum* was introduced in the XVII century, simultaneously with the development of the slave trade, which took sorghum grain with them as a food product. In the United States, sugar sorghum was first imported from China via France in 1851 under the name Chinese Amber. White and brown forms of sorghum, called Egyptian corn, were imported from Egypt in 1874. Currently, the main areas under sorghum are concentrated in the "sorghum belt": the states of Nebraska, Missouri, Kansas, Oklahoma, Texas (Assefa, Y. et al., 2024; McGinnis, M. J. et al., 2020). In the United States, the greatest success has been achieved in the selection, seed production and agricultural technology of grain sorghum. Only 14% of the world's acreage is concentrated here, and the gross harvest is about 40%. Currently, the main companies in the United States engaged in the production of sorghum seeds are Monsanto, Pioneer, Pfister, Gareth and Thomas, Syngenta, Frontier. In Europe (Italy, Romania, Hungary, Albania, Bulgaria, Hungary), sorghum crops occupy about 20% of the area (5 million hectares). ha).

In the XVIII century, there was a sharp increase in the area under sugar sorghum, which is associated with its use for the production of sorghum honey (Eggleston, G. et al., 2022). The spread of sugar sorghum contributed to the construction of small sugar factories. However, by the end of the XIX century, the production of sorghum sugar was abandoned.

Interest in sorghum increased after prolonged droughts, when other crops sharply reduced yields. In the context of climate change, there is a need to reorient to more sustainable forage crops that are highly nutritious and adaptable to drought and abnormal weather events. On the one hand, sorghum has always been characterized by increased grain productivity and drought resistance, and on the other hand, it remained a secondary, poorly studied crop, which determined the opinion about its unreliability. In addition, with the advent of new white-grain varieties, the possibilities of using sorghum for starch, alcohol (Abah, C. R. et al., 2020).



There are about 50 species of sorghum in the world. Classification of sorghum was started by American breeders, who at the beginning of the 20th century divided sorghum species into four groups: grain, sugar, broom and herbaceous, identified among them ecological and geographical subgroups and varietal types (Wondimu, Z. et al., 2021). A number of requirements are put forward for modern varieties: compliance with soil and climatic conditions, high potential yield, resistance to adverse conditions, high product quality, adaptability to mechanical processing. All these tasks can be achieved by various breeding methods (selection, hybridization, polyploidy, mutagenesis, etc.). In recent years, breeders' attention has been drawn to the prospect of creating hybrid populations (Wu, Y. P. et al., 2023).

Since 1977, new hybrid sorghum populations have been created based on phenotypically aligned but genotypically sharply different hybrid material. In sorghum breeding, a significant event is the creation of a rice-like form of sorghum (soriza), which has valuable nutritional properties. Soriz grain is characterized by good vitreous, high endosperm hardness and therefore high extrusion capacity, good taste, and resistance to diseases (Dremlyuk, H. K. et al., 2020; Voitovska, V. I. et al., 2022).

The main areas of breeding work for grain sorghum are: early ripening, suitability for mechanized harvesting, grain yield and quality (starch, protein, tannin, lysine content) (Gichile, H. 2022; Treviño-Salinas, M. et al., 2021). With the advent of such varieties, prospects open up for the use of grain for starch production, in the production of gluten-free bakery products (Szabłowska, E. et al 2021; Gómez, M. 2022; Khoddami, A, et al., 2023).

The main direction of sugar sorghum breeding is low growth, resistance to lodging, early ripening, disease damage, high yield of green mass, high content of protein and sugars in green mass (Herniwati, H. et al., 2024). The world has developed technologies for obtaining feed concentrate with a sugar content of 50-55% for a balanced sugar-protein ratio in animal feeding, production of food syrup for the confectionery industry, production of bio-alcohol, etc. (Leite, P. et al., 2020).

On average, over the years of research, in terms of nutritional value, namely the highest content of protein, fat and carbohydrates among the studied hybrids, American – Prime stood out, whose caloric content was 320 kcal., from the French – hybrid-Burggo with a caloric content of 318 kcal. The highest values of thiamine were found in the seeds of hybrids of American selection – Yuki and Prime, which amounted to – respectively – 0.43–0.45 mg/100 g. in the seeds of the American hybrid of grain sorghum – Prime, the highest biotin content was established – 0.018 mg/100 g. The studied hybrid of grain sorghum of the American selection Prime, over the years of research, was characterized by the highest Na content in its composition, which was – 26 mg/100g. as a result of the research, it was revealed that the Co content in all the studied hybrids of grain sorghum was in the same amount and amounted to – 2.0 mg/100 g. the highest Al content was found in the seeds of French hybrids, these indicators were at the level of 1,550 to 1,555 mg/100 g. In terms of B content, the American Yuki hybrid turned out to be the best, since the content of this trace element was 0.347 mg, while the French Burggo hybrid had the lowest boron content – 0.325 mg. The seeds of the American hybrid sorghum grain Prime 160 have the highest content of such a trace element as zinc at the level of 2.15 mg/100 g.

There are 5 types of sorghum in Ukraine, 4 of them are cultivated, mainly in the southern parts of the country. Dzhugara and sugar sorghum are grown in small areas in the steppe. Important varieties and hybrids in the steppe zone of Ukraine: Ukrainian 107, Kuban red 1677, Genichesk 1, Steppe hybrid 5, feed hybrid 5, Orange 160.



The agricultural sector of Ukraine in its functioning requires an urgent solution to the problem of further development and improvement of livestock productivity by organizing a scientifically based feed base and mainly focuses on the use of modern scientific achievements and the widespread introduction of the latest innovative and knowledge-intensive technologies aimed at actively increasing production volumes. In this regard, there is a need for special attention to technological solutions for storing sorghum grain, its effective use in feeding cattle with the study of the influence of a new feed ingredient in the diets of dairy cows on the physical and chemical parameters of milk, the physiological state of cows, their reproductive ability. Therefore, the study of the productive effect of sorghum grain when used in feeding cattle (dairy cows) as part of the feed diet is relevant.

What is the advantage of sorghum over the range of similar forage crops in biology? Grain sorghum, unlike corn, is not demanding on the presence of moisture in the soil, so it is perfectly suitable for those regions where the cultivation of moisture-loving fodder crops is difficult. Sorghum is less susceptible to pests and diseases, which not only reduces the cost of pesticides by an average of 30%, but also minimizes the risk of mycotoxins in feed. The structure of the plant does not allow fungi to actively develop (Suszkiw, J. 2023; Lee, S. et al., 2022).

Problems with water supply are extremely acute. According to the transpiration indicator, sorghum bypasses the main fodder crop - silage corn, a high yield of which can be obtained only with a high level of moisture. For example, sorghum consumes only 300 parts of water per unit of dry matter. For comparison, Sudan grass - 340, corn - 388, wheat-515.

There is no universal culture that meets absolutely all the requirements of livestock breeders. Moreover, it is also impossible to ensure a timely conveyor belt with one crop. Therefore, the selection of the most appropriate and hardy plants that can ensure the production of products despite stressful conditions is the best option. In this case, sugar sorghum is considered as the only alternative to using corn as a silage crop. After all, when it is grown outside irrigated areas, corn loses all its advantages as a highly productive plant. (Getachew, G. et al., 2016; Pujiharti, Y. et al., 2022).

In terms of the content of basic nutrients, sorghum grain is practically not inferior to corn. It is characterized by a high protein content (from 11%) and an increased lysine content (protein quality depends on this amino acid). According to scientists, increasing the amount of lysine by 0.1 g increases the level of protein digestibility per 1 g per 100 g of feed. Sorghum grains also have a high starch content (Beta, T. et al., 2000).

Sorghum contributes to the achievement of average weight gains similar to those achieved when feeding cattle on fattening grounds with a diet with corn. Sorghum not only has a positive effect on the growth and development of farm animals, but also improves the quality of meat due to its low content of polyunsaturated acids (Ochieng, B. et al., 2020; Jiao, J. et al., 2022).

There are several types of sorghum, and each has its own preferences. Grain sorghum is a fodder, food and technical crop. Sorghum grain is often used for the preparation of mixed feed, as well as as a concentrated feed not only for pigs, but also for cows, horses and poultry. The nutritional value of sorghum grains is quite high, in its composition this crop is very similar to corn and barley, which belong to grain crops. Sorghum has significantly more protein than corn, but instead it is inferior in such a factor as digestibility of substances (Ronda, V. et al., 2019).

Experts say that the use of sorghum grains in feed additives is equivalent to barley grains, pigs give the same increase and quality of meat. But there is one advantage of this crop, which is manifested in the fact that the yield of sorghum significantly exceeds spring



barley, so you can get twice as much pork from 1 hectare of sorghum as from 1 hectare of barley.

Sorghum grains contain 12-15 percent protein, about 70 percent starch, and 3.5 - 4.5 percent fat. In one hundredweight of grain, there are from 118 to 130 feed units. This indicator of nutritional value is considered quite good.

Some experts insist that the total percentage of sorghum grains in pig feed should be approximately 30-50 %, while they note accelerated growth of piglets, especially late farrowing. Pork turns out to be a dense, intense pink color and is well sold out on the market (Sotak, K. M. et al., 2015; Thomas, L. L. et al., 2020).

Sorghum grain is covered with a dense shell, during feeding it is not fully digested and transits through the gastrointestinal tract. Sorghum proteins and starches are digested in the rumen for up to two days (Yahaghi, M. et al., 2014; Risyahadi, S. T. et al., 2023). Therefore, it is better to pre-process sorghum grain before use:

- Grinding is the cheapest way. Sorghum is processed almost in the same way as corn. Good grain grinding up to 1.8 mm for better assimilation.
- Flattening, pre-treated with steam.
- Flattening of dry grain.
- Extrusion.

All these methods of pretreatment of grain give different degrees of digestibility. The "glassy" state of the endosperm slows down the breakdown of starch and proteins in the rumen, which reduces the risk of acidosis and optimizes the delivery of dietary proteins digested in the intestines.

When feeding sorghum grain, the consumption of dry matter decreases (Aguerre, M. et al., 2009). Unlike traditionally used grain types, sorghum is digested very slowly in ruminant Rumen due to the fact that sorghum starches and proteins are more resistant to enzymes. On meat animals, this is not essential, but during feeding dairy cattle and raising calves, problems may arise. When flattening with steam treatment, eating can be increased by 15%, but this treatment greatly increases the cost of food.

Sugar sorghum and sorghum-Sudan hybrid are successfully used for silage and haylage. Such top dressing is simply irreplaceable in winter in the diet of feeding pigs and other farm animals. Sorghum silage has a pleasant aroma, reminiscent of fruit, its taste qualities are quite high, so it is much better eaten by animals. The energy content in the sorghum crop is 18.3 MJ per kilogram (Jabbari, H. et al., 2011; Cattani, M. et al., 2017; Guo, F. et al., 2024).

Sorghum produces a green mass from the beginning of July to the end of August, surpassing other crops in yield. After mowing, sorghum grows quickly and vegetates until late autumn. With timely mowing for green fodder, it can produce 2-3 mowing per year.

Some sorghum varieties retain the ability to effectively silage their green mass for up to one and a half months from the moment of the optimal phase (milk-wax) of grain ripeness. This means that for Farms Limited in harvesting facilities and transport equipment, this crop is a real godsend.

Sorghum is suitable for silage. At the same time, its nutritional value will be lower than that of corn silage. The actual composition may vary depending on hybrids, harvesting dates, and storage losses.

The efficiency of sorghum silage depends on the level of livestock productivity. (Abdelhadi, L. O. et al., 2006). Experiments conducted on lactating cows proved that the complete replacement of corn silage with sorghum silage did not affect milk yield (Zhang, S. et al., 2024). However, such results were obtained by adding starch sources (such as corn flour) to the sorghum diet to compensate for the lower starch content in sorghum silage compared to corn silage. At the same time, there are opinions that changing the



type of silage and including starch sources in the diet will affect the nature of fermentation in the rumen (Pimentel, J. et al., 2013; Li, S. S. et al., 2020; Lv, X. et al., 2023).

What to be afraid of when using sorghum in feeding farm animals? It is necessary to pay attention to the sorghum variety itself. Since some varieties have a high percentage of tannins (it does not affect the feed value, but affects its digestibility and digestion, tannin itself is an astringent); monoenzymes can be added to improve digestion. In modern hybrids, the tannin index is low, on average 0.3-0.5%, which has a positive effect on feed digestion, but it is necessary to pay attention to the indicators. It is also worth considering the indicators of hydrocyanic acid - it is not allowed in sorghum. In silage, its neutralization occurs in about 1-2 weeks naturally.

**Discussion.** The analysis of information sources covers a wide range of issues related to the production and use of sorghum, including its history, global distribution, breeding, nutritional and feed value for animals.

Concluding the review of known sources on the use of sorghum as a priority fodder crop in the context of climate change, it should be noted that climate change will continue to affect many areas in the entire chain of feed and food production, and therefore the selection of fodder crops adapted to the impact of negative climatic factors becomes particularly relevant.

Encouraging producers to resume sorghum cultivation is based on the high potential of Ukraine in the form of acreage for this crop, the projected growth of which to 1-1.3 million hectares indicates its prospects. If we take into account adaptability, compared to corn, this crop is less demanding of moisture, which makes it suitable for regions with irrigation problems. In the face of climate change, this is an important advantage. No less significant is the search for areas of sorghum breeding and obtaining hybrids that will produce high yields in different climatic zones of Ukraine. Sorghum has a high nutritional value, which can contribute to its wider use in the food industry (gluten-free products, starch, alcohol). This promising crop is a valuable feed for livestock, pigs, and poultry. At the same time, it is important to take into account the nuances of digestibility and methods of pre-processing grain. The introduction of this crop into the feed wedge of farms for the production of livestock products will allow timely receiving a sufficient amount of sorghum grain and harvesting silage necessary for feeding cattle, especially lactating cows, which will contribute to obtaining high-quality dairy and meat products and preserving the health and productive longevity of livestock.

**Conclusions.** Thus, the spread of sorghum in the world indicates the great potential of this crop. Due to the origin and species diversity of sorghum, even in the driest and hottest regions of the world, unlike other agricultural crops, it allows you to get stable, high yields of grain and green mass. This makes it one of the leading grain and food crops. The use of sorghum silage is an effective solution in animal husbandry, especially in conditions of shortage of corn silage. However, for optimal effect, it is recommended to adjust the diet and carefully control the quality of feed. At the same time, the potential of this culture in Ukraine is still far from being revealed.

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